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SOIL EROSION CONTROL STRUCTURES ON SKIDTRAILS

By

W. J. KIDD, Jr.

Division of Watershed Management Research

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PLEASE NOTE

This is the first of a new series of reports to be issued by the Intermountain Forest and Range Experiment Station. These reports will be designated "U.S. Forest Service Research Paper INT- --." They replace the Research Paper series, the last one of which was Research Paper 71.

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THE PROBLEM

A common practice in Idaho and other western states is to log steep slopes using a jammer and crawler tractor conjunctively. Jammer logging requires a closely spaced road net where roads are commonly 100 to 400 feet apart. The jammer, used for skidding uphill, and the tractor,[1] for skidding downhill, create bare skidways which in turn may become important sources of sediment in streams. Although the use of high-lead systems of cable logging is increasing, such equipment also leaves occasional skidtrails on steep, cutover slopes.

Proper treatment of bared skidtrails after logging reduces the hazard of potential erosion. Commonly, treatment consists of constructing retention structures from logging debris or diversions by using hand shovel or bulldozer. Objectives of this study were: (1) to determine the optimum spacing distances between manmade structures for preventing excessive rilling, and (2) to determine which of several structures or diversions provides the most effective controlled disposal of sediment-laden water that originates on skidtrails.

[1] Haupt, H. F. 1960. Variation in areal disturbance produced by harvesting methods in ponderosa pine. Jour. Forestry 58: 634-639.

ESTABLISHMENT OF STUDY AREAS

During the summers of 1953, 1954, and 1955, 86 skidtrails on four National Forest timber sale areas (see map, fig. 1) were treated by building either slash dams (fig. 2), or diagonal log water bars (fig. 3).[2] Seventy skidtrails were selected on soil derived from granite of the Idaho batholith; 16 were on soil derived from Columbia River basalt. An additional 14 skidtrails were treated by lopping and scattering slash on the skidtrail surface; of these, 10 were on granitic soil and four on basaltic soil. Five other skidtrails on basaltic soil were treated with cross ditches dug by a D-4 type bulldozer and hand shovel.

[2] Acknowledgment is made to the erosion control crews of the Boise and Payette National Forests for building the structures under the guidance of Paul E. Packer and Harold F. Haupt of Intermountain Forest and Range Experiment Station.

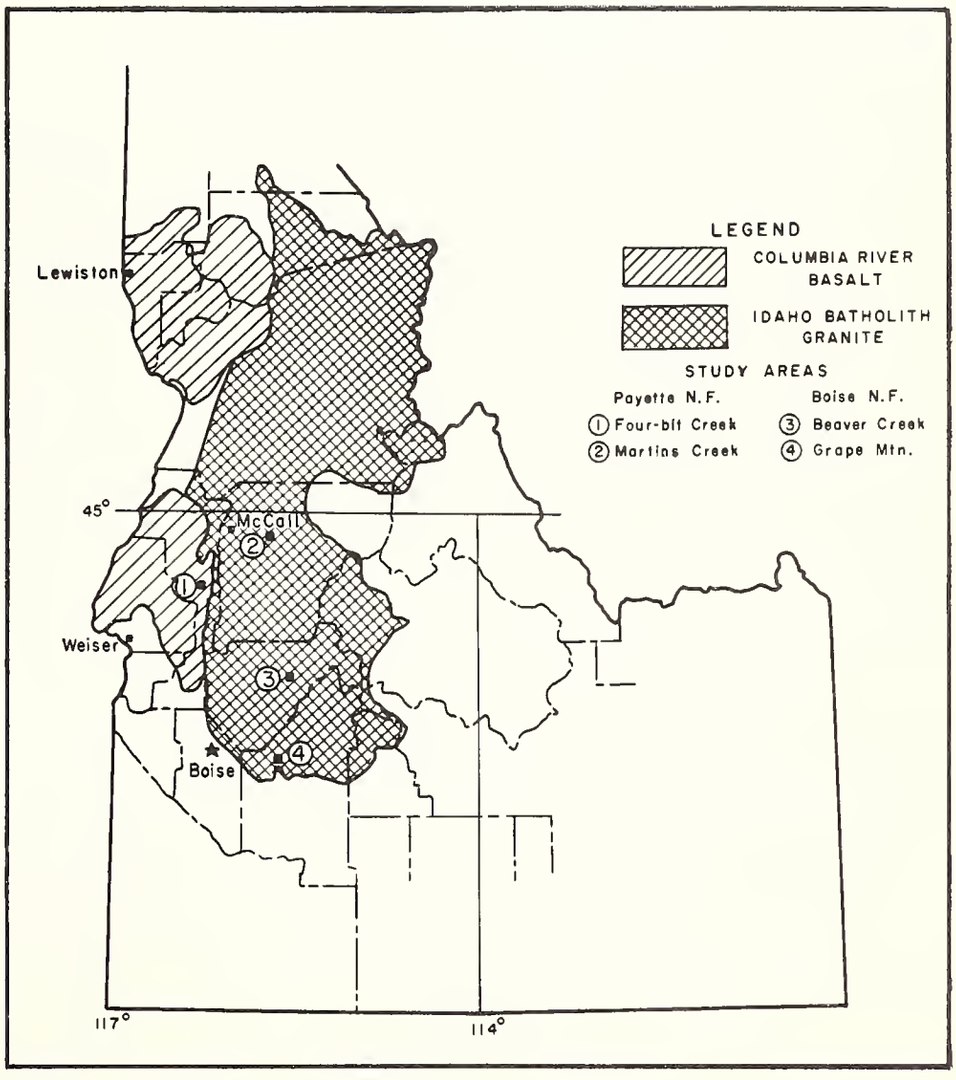

Figure 1.--Location of study areas on soils derived from granite and basalt in west-central Idaho.

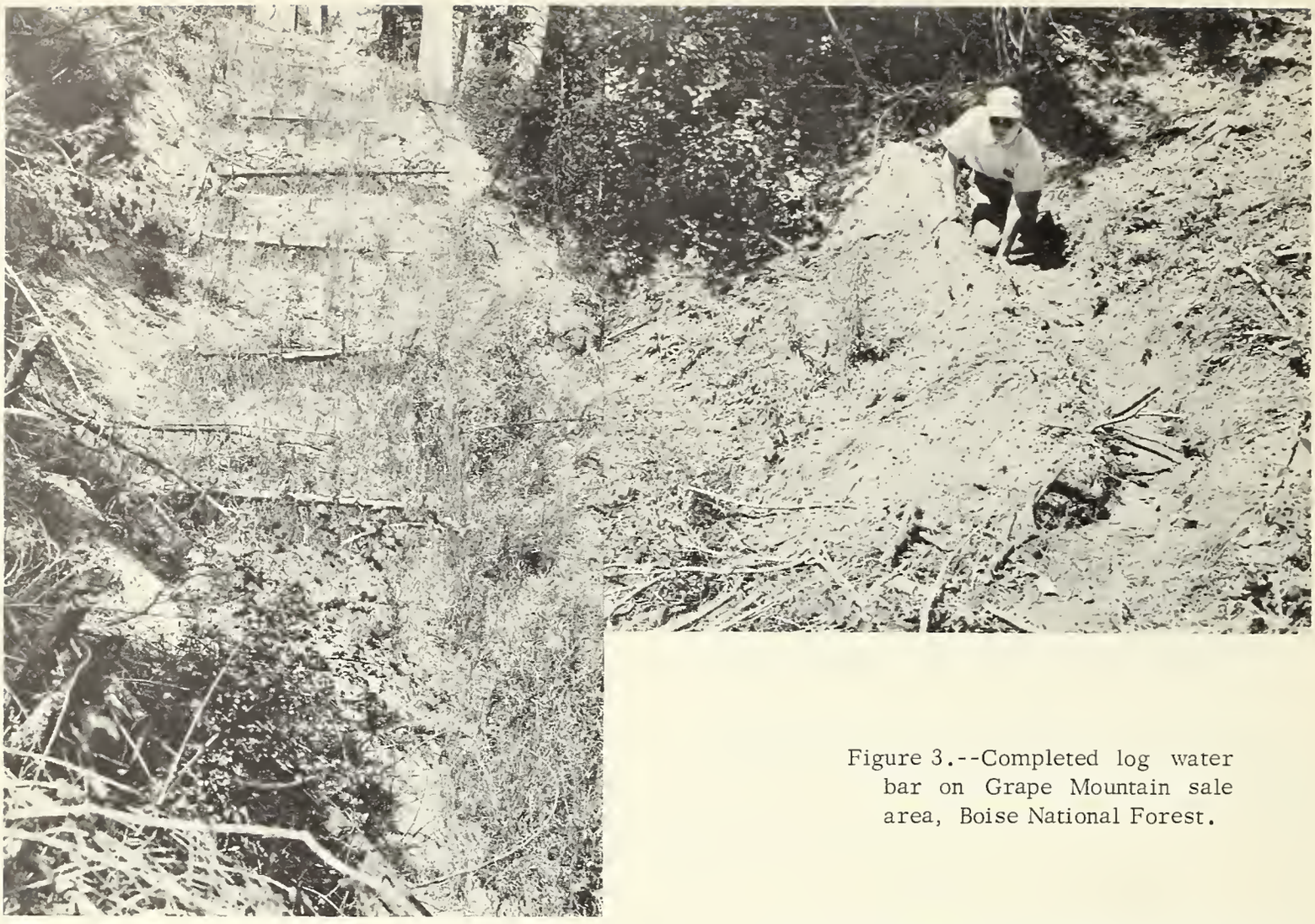

Figure 2.--Completed slash dams on Martins Creek sale area, Payette National Forest.

Figure 3.--Completed log water bar on Grape Mountain sale area, Boise National Forest.

Spacing of the structures--10, 25, 50, and 75 feet--was based upon Packer's[3] observations in 1952 of erosion on logging haul roads and skidtrails. He measured the distance from a control structure to the head of the nearest active erosion gully or rill immediately below, then computed the average distance from structure to the point of active erosion for three slope classes: less than 20 percent, 20 to 40 percent, and 40 to 60 percent. The above spacings were then derived by subtracting three times the standard error of estimate from the average distance to erosive cutting. As part of this new study, Packer's recommended spacings were field tested on skidtrail slopes ranging from 20 to 90 percent.

Following installation of the water-control structures, the skidtrails were broadcast seeded to the following plants:

Yellow sweetclover	Melilotus officinalis
Timothy	Phleum pratense
Tall oatgrass	Arrhenatherum elatius
Orchardgrass	Dactylis glomerata
Bulbous bluegrass	Poa bulbosa
Crested wheatgrass	Agropyron cristatum
Intermediate wheatgrass	A. intermedium
Winter rye	Secale cereale

STORMS

When erosion results from overland flow but only the effects are measured, it is highly desirable to know something of the timing and severity of the storms that produce the overland flow. Unfortunately, yearlong rainfall and snowmelt data are unavailable for the four study areas because of their remoteness. However, available data from U.S. Weather Bureau stations nearby provide a basis for several extrapolations for the period 1954 to 1957.

1. The number of high-intensity summer storms on the study areas, was below the average.

[3] Packer, Paul E. Criteria for reducing erosion from logging on granite soils. 1954. (Unpublished report on file at Intermountain Forest and Range Expt. Sta., U.S. Forest Serv., Ogden, Utah.)

2. In December 1955, a medium-intensity rain fell on a shallow snowpack and caused above-normal runoff for that time of year. The rain was general over all four areas; the Martins Creek area was heavily damaged by erosion.

3. Rainfall and temperatures in January 1956 were above normal. The abnormally high rainfall probably caused additional damage to the study areas.

4. Heavy rains on snow in February 1957 probably yielded above-normal runoff from all study areas.

It may be presumed that overland flow was greater during the cool seasons of the year than that normally expected; however, only a few of the treated skidtrails were exposed to repeated surges of overland flow caused by high-intensity summer storms that are common in the mountains of central Idaho.[4] Thus, the overall weather potential for erosion was probably moderate rather than exceptionally high.

FIELD OBSERVATIONS

Field observations were made in 1955 and 1957. In 1955, 105 skidtrails (excluding a few untreated ones on Grape Mountain) were inspected, and quantitative measurements of erosion were made. Rills and gullies were measured to ascertain the cubic-foot volume of soil displaced by overland flow; also, the volume of sediment trapped behind individual skidtrail structures was determined. Deep erosion was noted on 27 of the 80 skidtrails on granitic soil, and on 11 of 25 treated skidtrails on basaltic soil. The remainder of the trails had no measurable rills or gullies, but wherever evidence showed sheet erosion or soil creep, it was noted.

The four study areas were reexamined in 1957 and the various control structures rated qualitatively by using the numerical point system outlined in the Appendix. Each skidtrail interval, 569 altogether, was assigned a rating of points for five conditions; an average score was then calculated for each skidtrail. A low score meant that the structures were acceptably controlling erosion, and that the interstructure skidtrail surface was in good condition. An average of 1.0 represented complete protection; an average of 4.8 meant that all control structures were washed out and that the skidtrail surface was eroded severely.

[4] Kidd, W. J., Jr. 1961. High-intensity rainstorms on the Boise and Payette National Forests. U.S. Dept. Agr., Forest Serv., Intermountain Forest and Range Expt. Sta. Res. Note 81, 4 pp.

RESULTS

1955 QUANTITATIVE DATA

Table 1 shows the number of skidtrail intervals by study area and treatment and the percentage of each on which erosion was measured in 1955 and 1957. More skidtrail intervals, percentagewise, were eroded on Grape Mountain and Martins Creek than on Beaver Creek and Four-bit Creek because most of them were located on south, southeast, and southwest aspects, which supported correspondingly less reseeded vegetation than did the northerly aspects of Beaver Creek and Four-bit Creek areas.

Table 1.--Type of erosion by number of skidtrail intervals [1]

Area	Treatment	No erosion				Trace or sheet erosion				Rill erosion				Gully erosion			
		1955		1957		1955		1957		1955		1957		1955		1957	
		No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Beaver Creek (granitic soil)	Slash dam	57	73	37	48	15	19	11	14	2	3	14	18	4	5	15	19
	Log water bar	52	66	37	52	14	18	13	18	7	9	21	30	6	7	0	0
	Lop-and-scatter	3	75	3	70	--	--	--	--	[2] 2	25	[3] 2	30	--	--	--	--
Grape Mountain (granitic soil)	Slash dam	5	19	[4] 14	30	6	23	4	9	11	42	5	11	4	16	23	50
	Log water bar	16	27	[4] 78	78	21	35	13	13	15	25	9	9	8	13	0	0
	Lop-and-scatter	0	0	0	0	--	--	1	100	--	--	--	--	--	--	--	--
Martins Creek (granitic soil)	Slash dam	52	57	40	47	23	25	8	9	14	16	19	22	2	2	19	22
	Log water bar	13	25	31	49	15	28	3	5	25	47	21	33	0	0	7	11
	Lop-and-scatter	3	75	1	33	--	--	--	--	1	25	--	--	--	--	2	[5] 67
Four-bit Creek (basaltic soil)	Slash dam	48	72	31	47	9	14	9	14	9	14	7	11	0	0	19	29
	Log water bar	51	66	59	77	5	7	14	18	21	27	4	5	0	0	0	0
	Lop-and-scatter	4	100	3	90	--	--	--	--	--	--	1	[6] 10	--	--	--	--
	D-4 cat and shovel ditches	4	15	8	30	6	22	3	16	12	44	16	84	5	19	0	0

[1] Based on total number of treated skidtrail intervals examined in 1955 and 1957.
[2] The entire length of one skidtrail was eroded, and 25 percent of another. Overall, 25 percent of the total length of five skidtrails was eroded.
[3] The entire length of one skidtrail was eroded, and 50 percent of another. Overall, 30 percent of the total length of five trails was eroded.
[4] Includes additional intervals treated late in 1955.
[5] Two skidtrails were 100 percent washed out; the third was not, hence 67 percent of the total length of three skidtrails was eroded.
[6] Since 40 percent of the length of one skidtrail was eroded, 10 percent of the total length of four skidtrails was eroded.

The volume of soil displaced is shown in table 2. Generally, more sediment was eroded from longer skidtrail intervals than from shorter intervals, but the increased erosion was not necessarily proportional to the increased distance between structures. Moreover, as much soil was eroded from some gentle slopes as from steeper slopes.

Table 2.--Average volume of soil eroded per skidtrail by slope gradient class, structure spacing, and soil parent material

Slope gradient (Percent)	Structure spacing	Average volume of soil eroded per skidtrail	
		Granite	Basalt
	Feet	Cu. ft.	Cu. ft.
20-30	25	[1]1.92(4)	1.82(4)
	50	5.14(3)	4.94(6)
	75	20.42(1)	--
40-50	10	1.84(5)	--
	25	2.13(4)	--
	50	9.06(1)	.54(1)
60-70	10	.63(1)	--
	25	4.62(5)	--
	50	5.91(3)	--
		(27)	(11)

[1] Numerals in parentheses are numbers of skidtrails measured.

A series of statistical tests confirmed these conclusions. Values for missing data were estimated by approved methods. An analysis of variance showed structure spacing to be highly significant, whereas slope class was not significant. In other words, irrespective of slope gradient (greater than 20 percent), an increase in spacing between structures is accompanied by an increase in soil movement that often is appreciable.

On the basis of sediment trapped, the control structures generally demonstrated varying degrees of trap efficiency. The two types of structures, log water bars and slash dams, although comparable in size, handled overland flow in distinctly different manners. The log water bars diverted overland flow and sediment off the skidtrail and onto the forest floor; whereas the slash dams filtered sediment from the overland flow and did not divert the running water from the skidtrail surface. Structures of both types trapped more sediment on basalt-derived soil than on granite-derived soil (table 3). Gentler terrain on the basalt area meant that most of the skidtrails were located on the gentler (20-30 percent) slope class; Hence, velocities of sediment-laden flows were not great enough to seriously overtop or undermine the structures.

Although results of the 1955 study indicated some strong trends pertaining to relations between gross soil loss and spacing interval, the quantitative data were insufficient to warrant separating the skidtrails treated by slash dams from the trails treated by log water bars, or separating sidehill data from ravine data. Two years later, evaluation by qualitative indexes made it possible to separate the effects of structure type, slope gradient, soil parent material, and topographic location upon erosion.

1957 QUALITATIVE DATA

By the end of the second measurement period, many skidtrails showed few or no signs of erosion; others were healing rapidly; and still others were actively eroding. Why were these skidtrails responding so differently, and what were some of the contributing factors?

Performance ratings for each skidtrail (see Rating System, Appendix), regardless of the degree of erosion, were averaged and then classified first by soil against topographic location (table 4), and second by soil against slope gradient (table 5). Performance, by these ratings, meant the functioning of the structures with regard to overall effectiveness. An analysis of variance of data in table 4 showed that more erosion occurred in ravines than on hillsides--an expected result that was almost significant at the 5-percent level. Treatment (control structures) was

Table 3.--Sediment flow measurements, 1955

Soil type	Skidtrails established	Skidtrails eroded		Sediment eroded			
				Amount trapped		Amount not trapped	
		No.	Pct.	Cu. ft.	Pct.	Cu. ft.	Pct.
Granitic	80	27	34	31.91	29	79.83	71
Basaltic	25	11	44	25.32	78	6.97	22

Table 4.--Average performance ratings of control structures by type and location, 1957

Control structure	Location	Granitic soil	Basaltic soil
Lopping and scattering	Sidehill	2.42	1.14
	Ravine	3.53	2.42
Slash dams	Sidehill	1.91	2.19
	Ravine	2.56	3.65
Log water bars	Sidehill	1.88	1.67
	Ravine	2.36	1.58
Average--all structures	Sidehill	1.95	1.77
	Ravine	2.65	2.74

not significant in the analysis of variance because all types of structures were generally ineffective in ravine bottoms. Soil, also, was not significant for the similar reason that skidtrails located in ravines produced heavy soil losses regardless of parent material.

Disregarding topographic location, statistical analysis of data in table 5, exclusive of the 80- to 90-percent slope class, revealed that the difference in erodibility between soil derived from granite and that derived from basalt was almost significant at the 1-percent level. In other words, the structure rating values were lower on basalt; this suggests that basaltic soil is inherently less erodible and more productive in growing ground cover that is effective in controlling erosion. This trend agrees with results in Oregon and northern California reported by Anderson[5] and André and Anderson.[6] Their studies indicated that soils developed from acid igneous rock (including granite) are about 2-1/2 times as erodible as soils developed from basalt.

As expected, the interactions of soil and structure treatment (S X ST) and soil and slope gradient (S X SG) were most important. They were significant at a level between 1 and 5 percent. This means that soil had a variable effect on the structure performance rating, depending upon the type of structure used and slope class. The overall effect of structure treatment alone was almost significant at the 5-percent level. In general, the water-diverting structures (log water bars and cross ditches) were more effective than the sediment-filtering methods (slash dams and lopping and scattering of slash).

A SPACING GUIDE FOR SKIDTRAIL STRUCTURES

During the 1957 rating of the condition of structures and skidtrail surfaces, additional notes were made for item 5, "General observations," in the Appendix. If the structures were judged to be spaced too far apart or too close together (based on amount and type of erosion present), an estimate was made of what would have been the correct spacing. These estimates were later averaged with those measurements on skidtrails whose structure spacings were considered correct to aid in determining optimum structure spacing for different degrees of slope.

[5] Anderson, H. W. 1954. Suspended sediment discharge as related to streamflow, topography, soil, and land use. Amer. Geophys. Union Trans. 35: 268-281.

[6] André, J. E., and H. W. Anderson. 1961. Variation of soil erodibility with geology, geographic zone, elevation, and vegetation type in northern California wildlands. Jour. Geophys. Res. 66: 3351-3358.

Table 5.--Average performance ratings by type of structure, soil parent material, and percent of slope, 1957

Structural treatment	Soil parent material	Percent of slope				
		20-30	40-50	60-70	80-90	All slope average
Lopping and scattering	Granite	2.44	3.28	3.02	--	2.93
	Basalt	2.32	1.24	1.24	--	1.60
Slash dams	Granite	2.50	2.10	2.08	--	2.15
	Basalt	3.00	1.56	2.20	--	2.25
Log water bars	Granite	1.84	2.24	1.90	1.12	1.78
	Basalt	1.80	1.38	1.44	--	1.54

On 14 of the 40 skidtrails treated with slash dams, and on 12 of the 41 skidtrails treated with log water bars or shovel ditches, the structures were deemed to be too far apart for maximum effectiveness. Contrariwise, on three trails treated with slash dams and three trails with log bars, the structures were considered to be spaced too closely. Structures on these six skidtrails were installed at 10-foot intervals.

Spacings recommended in table 6 are based on three sources of data:

1. Packer's unpublished study of 73 skidtrail intervals. (See footnote 3.)

2. Customary spacing used by the Boise National Forest erosion control crews.

3. Author's analysis of 569 skidtrail intervals, reported herein.

Table 6.--Recommended spacing for skidtrail erosion control structures on soils derived from granite and basalt in west-central Idaho.

Slope (Percent)	Spacing on--			
	Soil from granite		Soil from basalt	
	Sidehills	Ravines	Sidehills	Ravines
	Feet	Feet	Feet	Feet
10	65	50	90	80
20	50	35	70	65
30	40	25	60	50
40	30	20	50	40
50	20	15	40	35
60	15	10	25	20
70	10	10	15	15

When installing erosion control structures on skidtrails after logging, these spacings are recommended as basic distances. Certain factors must be considered in deciding which spacing to use under different conditions. Wider spacing is allowable on soil from basalt because it is less susceptible to erosion than soil from granite. Any area whose potential runoff may drain down a skidtrail should be examined carefully; for example, a ravine skidtrail that drains several acres needs control structures spaced more closely than a sidehill skidtrail that drains a very small area.

Any decision about the type of structure to be used depends on the situation that prevails on a given area. Slash to build slash dams may not be available in sufficient quantities; occasionally small straight poles for log water bars may be in short supply. Results of this study show that slash dams should not be recommended for sidehill use because they do not divert water and are relatively costly. Construction costs estimated by a District Ranger[7] were $2.00, or 1.25 man-hours per structure. This same Ranger also stated that after a year it was necessary to dig diagonal cross ditches below every third slash dam to divert water from the skidtrails because spring runoff had created erosion gullies between structures. Slash dams are recommended for use in ravines only if they can be built large enough to filter out most of the sediment and materially retard the waterflow.

Log water bars are excellent for diverting water from either flat or shallow, trough-shaped sidehill skidtrails. Construction time is about 1 man-hour per structure. Log water bars usually do not deteriorate as quickly as slash dams, which usually become ineffective after 1 or 2 years.

Hand-shoveled or bulldozed cross ditches, which are no more than water bars without the log, may be substituted for log water bars. However, slough from natural causes or from trampling by game may reduce the effectiveness of logless water bars; hence it is prudent to make every third or fourth structure a log water bar to insure that overland flow will be diverted. Of the erosion control structures, cross ditches are considerably quicker and less expensive to build. Depending on depth of soil, terrain, and structure spacing, construction time for a hand-shoveled ditch varies from 5 to 10 minutes.

Lopping and scattering slash is recommended on gentler slopes and where undercutting by surface flow will be at a minimum. The slash provides a mulch that protects the bared skidtrail surface during rainstorms, retards overland flow, and improves site conditions for plant invasion and establishment of reseeded species.

[7] Office memo dated June 14, 1957, from R. Stemple, formerly District Forest Ranger, Krassel Ranger District, Payette National Forest. Martins Creek study area is on this District.

SUMMARY

Erosion measurements on 569 intervals of 105 logging skidtrails revealed the following:

1. Erosion is greater and rate of healing is slower on soil derived from granite than on soil from basalt.

2. More soil is eroded from skidtrails unavoidably located in ravine bottoms than from trails on sidehills.

3. Control structures that divert water off the skidtrail onto undisturbed forest floors are superior to those that only retard water movement and filter out sediment along the skidtrail.

4. Any increase in spacing between control structures is accompanied by increase in soil movement.

5. Optimum spacing between erosion control structures depends upon the percent of slope, whether location of the skidtrail is on a sidehill or in a ravine, and the soil parent material.

APPENDIX

RATING SYSTEM FOR SKIDTRAILS AND SKIDTRAIL STRUCTURES

1. Erosion between structures
   - 1.0 = little or no erosion
   - 1.2 = moderate sheet erosion
   - 1.4 = pronounced sheet erosion
   - 2.0 = few rills
   - 2.5 = moderate rilling
   - 3.0 = numerous rills
   - 4.0 = single shallow gully
   - 4.5 = single deep gully
   - 5.0 = deep gullies
   - 6.0 = washout

2. Revegetation of skidtrail
   - 1.0 = excellent grass cover
   - 1.2 = moderate grass cover
   - 1.5 = poor grass cover
   - 2.0 = numerous shrubs
   - 2.2 = moderate amount of shrubs
   - 2.5 = few or no shrubs
   - 3.0 = numerous tree seedlings
   - 3.2 = moderate number of seedlings
   - 3.5 = few or no tree seedlings
   - 4.0 = very little cover or bare

3. Condition of structures
   - 1.0 = good
   - 2.0 = fair
   - 4.0 = broken
   - 5.0 = washed out

4. Sediment flow and sedimentation
   - 1.0 = stopped by structures
   - 2.0 = structures overtopped
   - 2.0 = "end-around" flow
   - 4.0 = "through or under" flow

5. General observations
   - 1.0 = structures spaced about right
   - 2.0 = structures too close
   - 4.0 = structures too far apart
   - 5.0 = washout

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(FOR YOUR CARD FILE)

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1963. Soil erosion control structures on skidtrails. U.S. Dept. Agr., Forest Serv., Intermountain Forest and Range Expt. Sta., Ogden, Utah. 8 pp., illus. (U.S. Forest Serv. Res. Paper INT-1)

More than 500 measurements of erosion on 105 logging skidtrails showed that: (1) erosion is greater and healing is slower on granitic than on basaltic soils, and is greater in ravine bottoms than on sidehills; (2) the best control structures divert water onto undisturbed forest floor rather than merely retarding its flow; (3) increase in spacing between control structures is accompanied by increase in soil movement; and (4) optimum spacing between control structures depends upon slope, location of skidtrail, and soil parent material.

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